Volume 108, Number 4, July-August 2003
Journal of Research of the National Institute of Standards and Technology

News Briefs

General Developments

Inquiries about News Briefs, where no contact person is identified, should be referred to the Managing Editor, Journal of Research, National Institute of Standards, and Technology, Building 101, Room E215, Gaithersburg, MD 20899-2500; telephone: (301) 975-3577.

NIST-DEVELOPED WIDEBAND SAMPLING VOLTMETER PROVIDES INCREASED ACCURACY TO CALIBRATION LABORATORY CUSTOMERS

A wideband (10 Hz to 1 GHz) sampling voltmeter (WSV) has been developed that greatly improves NIST's ability to perform accurate measurements of various electrical waveform parameters. Three replicas of this instrument have been delivered to the sponsors of this work for use in their calibrations laboratories. One WSV unit is being used by Sandia National Laboratories to characterize pulse response of oscilloscopes at peak amplitudes up to 100 V. Accuracy requirements precluded the use of commercial equipment for these measurements. At the Army and Air Force's primary metrology laboratories, two other units are being used to measure the ac gain flatness of state-of-the-art commercial ac voltmeters and calibrators at frequencies up to 30 MHz. The combination of wide bandwidth, large dynamic range, and high accuracy requirements make these measurements extremely difficult to perform. The two laboratories began using the NIST WSV after failing to meet their goals with traditional thermal transfer technology. A fourth WSV is being used at NIST in the pulse calibration service, and a fifth will be used soon in a distorted power calibration service.

The instrument consists of a mainframe unit and a set of two sampling comparator probes. Two types of probes have been developed. One probe type is designed for the sampling of high-speed signals in a 50 Ω environment, and the other for the sampling of lower bandwidth signals in a high impedance environment. A key feature of both probe types is that their gain flatness response may be conveniently characterized using step response techniques. Several instrumentation manufacturers have expressed interest in the commercialization of the WSV.

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SIMPLIFIED APPROACH TO CALCULATING GLOBAL WARMING POTENTIALS DEVELOPED

NIST scientists, in collaboration with researchers from the Institute of Energy Problems of Chemical Physics, Russian Academy of Sciences, have developed a simplified method of calculating global warming potentials (GWPs) of halogenated compounds. The method appears in a paper published in the *Journal of Photochemistry and Photobiology. A. Chemistry* **157**, 211-222 (2003), along with measured infrared absorption cross sections and integrated band intensities for 21 haloalkanes of industrial importance. This new approach for GWP calculation is valid for compounds whose principal IR absorption bands do not overlap those of carbon dioxide and are sufficiently long-lived that their tropospheric vertical distributions are approximately constant. This is true for numerous compounds of industrial interest, which are expected to contribute to the global warming. The method utilizes the measured infrared absorption cross-sections of the molecule along with the measured outgoing infrared emission of the earth to derive the radiative forcing. The radiative forcing together with an atmospheric lifetime determined from laboratory photochemical kinetic measurements is then used to derive the GWP of the compound. For the 12 compounds for which literature values exist, the values calculated by this simplified approach are found to be in very good agreement with the results of comprehensive atmospheric modeling.

The infrared absorption spectra measured in this work along with spectra for three fluoroethers are posted on the web at http://nist.gov/kinetics/spectra/spectraindex.htm. A number of UV absorption spectra measured at NIST can be found at the same web site.
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RESEARCH PROGRESSES TOWARD CRITICAL MOLECULAR ELECTRONICS MEASUREMENTS

Research at NIST and a private company is progressing toward reliable methods for measuring the electrical behavior of molecular electronic devices, an emerging nanotechnology eyed for future integrated circuits.

Using a crossbar test structure consisting of a molecular monolayer sandwiched between a series of perpendicular metal wires, collaborators at separate facilities recorded nearly identical electrical measurements. This step, along with others taken to eliminate potential sources of error, ensures that the measured behavior is directly attributable to the device and not the experimental set up.

Electrical (current-voltage, or IV) measurements of crossbar devices containing eicosanoic acid exhibit a controllable, two-state switching behavior that is due to the presence of the molecular layer. However, the molecular monolayer is not the sole cause. Rather, the switch-like behavior most likely arises from the interaction of the molecules with the electrodes. This example illustrates that the properties of molecular electronic devices are often determined not by the molecule alone, but by the entire device that consists of both the molecules and the attachment electrodes.

This two-state behavior was independently measured in two separate laboratories, indicating that it is not a measurement artifact and illustrating that these devices are robust enough to ship via conventional methods and remain active.

In addition to IV measurements, what well may be the first capacitance-voltage (CV) measurements of molecular monolayer-based devices were taken at NIST. These CV curves also show two-state behavior.

This work was first reported on April 2, 2003, at the Government Microcircuit Applications and Critical Technology Conference 2003.
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NIST/SEMATECH COLLABORATION LEADS TO BREAKTHROUGH ON INTERFACE STATE DENSITY EXTRACTION

A NIST scientist, in collaboration with researchers at International SEMATECH, recently completed a study of the proper use of capacitance-voltage measurements to extract interface state density of high dielectric-constant (alternate) gate dielectrics for metal-oxide-semiconductor (MOS) devices. Recently, quasi-static analysis has been used to extract the interface state density. The NIST scientist and his collaborators determined that this quasi-static analysis can give incorrect results and that a proper frequency dependent analysis is required.

As the lateral feature sizes of complementary metal oxide semiconductor field-effect-transistors are scaled downward, the gate dielectric capacitance must be increased in order to maintain the same drive current. Historically, this has been accomplished by decreasing the physical thickness of SiO_2. As the thickness of SiO_2 moves toward 1 nm, the gate leakage current becomes unacceptably high. Therefore, numerous alternate dielectrics (e.g., ZrO_2, HfO_2, Hf or Zr silicates, La_2O_3) with dielectric constants greater than SiO_2 recently have been under intense investigation. These dielectrics typically have a large density of electrically active defects near the silicon substrate (interface states). It is important to be able to measure the density of these defects accurately.
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OPTIMAL VECTOR-NETWORK-ANALYZER CALIBRATION ALGORITHM DEVELOPED BY NIST STAFF

NIST and PTB staff have completed StatistiCAL™, a software algorithm that combines a decade of experience in applying orthogonal distance regression and other iterative techniques to solving vector network analyzer (VNA) calibrations with an easy-to-use user interface. The new software features a robust algorithm capable of finding solutions even with poor initial estimates, greatly increasing its ease of use and broadening its applicability. The algorithm provides uncertainties of the estimated para-meters that account for both random and systematic errors in the VNA measurements, calibration model, and standards. The uncertainties in the solution are represented by a covariance

matrix that relates errors in both the VNA calibration and measurements of the device under test. In addition, the algorithm determines coverage factors based on the different numbers of degrees of freedom associated with various parts of the solution.

Researchers not only have shown that the new algorithm outperforms NIST's popular MultiCal® software in the presence of measurement noise, but they have performed experiments demonstrating the accuracy of the uncertainty estimates generated by the algorithm. Software implementing this method can be downloaded at www.boulder.nist.gov/dylan/.

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NIST RESEARCHERS DEMONSTRATE 120-ELEMENT FOCAL-PLANE ARRAY FOR CONCEALED WEAPONS DETECTION

Millimeter wavelength imaging is a natural approach for concealed weapons detection (CWD) because of the transparency of clothing and the spatial resolution achievable in this spectral region. However, large-format arrays of mm-wave detectors, analogous to CCDs in the visible region, do not yet exist. Recently, NIST researchers, working under the auspices of an Office of Law Enforcement Standards program, have demonstrated a 120-element focal-plane array of antenna-coupled microbolometers optimized for wavelengths near 3 mm (100 GHz frequency). The microbolometers are 1.6 μm × 10 μm strips of thin-film Nb, and are coupled to free space through Au slot-ring antennas that are 850 μm in diameter, while the overall array is 75 mm in diameter. A fast, low-noise readout for the array has been built, which allows the sensitivity of the array to be limited by the fundamental Johnson noise of the microbolometers. Electrical noise-equivalent power for each pixel is approximately 100 pW/Hz$^{1/2}$, with a response time of 400 ns. The focal-plane array enables development of several types of systems envisaged for CWD applications, including portals for airport passenger screening and police cruiser-mounted standoff systems.

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SOURCE OF DECOHERENCE IN JOSEPHSON QUBITS IDENTIFIED BY NIST RESEARCHERS

Josephson junctions are good candidates for a quantum computer with recent experiments demonstrating reasonably long coherence times, state preparation, manipulation and measurement, and coupling of qubits for even-tual gate operations. Since a practical quantum computer will require extended coherent times, a detailed investigation and understanding of all possible decoherence modes is important. NIST scientists in Boulder recently demonstrated that a major source of decoherence in Josephson qubits arises from spurious microwave resonances that are formed from states within the tunnel junction. A model has been developed that connects the subgap current-voltage characteristics with the magnitude of the resonances as well as the magnitude and density of $1/f$ critical-current fluctuations. This work provides valuable guidance for future Qubit development by demonstrating the need for materials research directed at reducing critical-current fluctuations in tunnel junctions.

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NIST RESEARCHERS DEVELOP MICROCALORIMETER ARRAYS USING SURFACE MICROMACHINING

The single-pixel superconducting transition-edge sensor (TES) x-ray microcalorimeters developed at NIST enable x-ray spectroscopy with energy resolution that is 10 to 100 times better than conventional semiconductor detectors. This high-energy resolution has proven useful in a variety of applications, including x-ray microanalysis in a scanning-electron microscope. NIST researchers now have developed 64-pixel arrays of microcalorimeters to decrease data collection times, enable imaging, and provide an order of magnitude improvement in the analysis of nanoscale particle, thin films, and trace contaminants in materials.

The researchers fabricated 64 pixel arrays of TES microcalorimeters using surface-micromachining techniques. Until now, microcalorimeters always have been fabricated using bulk micromachining techniques where thermal isolation of the detector is achieved by removing the Si substrate from behind the detector, leaving the detector supported by only a thin membrane of silicon nitride. The resulting device is extremely fragile, requires complex double-sided processing, and the possible device geometries are limited. In surface micromachining, detectors are fabricated on a silicon nitride membrane "table" supported by legs on top of a solid substrate. The resulting device is robust, and the space beneath the pixel can be exploited for readout circuitry. This new processing technique will make it

possible to build arrays of high-performance TES microcalorimeters for a variety of materials analysis and astronomical applications.
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NIST RESEARCHERS MEASURE THE SINGLE ELECTRON SPECTRUM OF InAs QUANTUM DOTS

Quantum dots (QD)—nanometer-scale semiconductor islands—are being investigated for a variety of optoelectronic applications, including use as single photon-on-demand sources. Such a source operates by tunneling a single electron and hole onto a QD where they recombine to produce a single photon. This type of single photon source would be used for new optical calibration devices and could become part of quantum communications systems.

To understand the behavior of these devices, it is necessary to measure the electrical properties of individual QDs at the single electron level. NIST researchers recently have measured the single electron spectrum of a semiconductor heterostructure containing InAs self-assembled quantum dots. In this experiment, a single electron transistor (SET) is fabricated on a semiconductor structure containing InAs QDs and an underlying n-doped GaAs layer. As the bias voltage of the n-doped layer is decreased, electrons tunnel from the n-doped layer into the neighboring quantum dots and are detected by the SET. The measurement was made possible by a new data acquisition system that cancels the linear background signal originating from the bias voltage of the n-doped layer with a balancing voltage applied to a side gate of the SET. This experiment will allow researchers to understand and control the tunneling of individual electrons into a quantum dot, and will serve as an important step toward making an electrically controlled single-photon source.
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NIST RESEARCHERS DEVELOP NEW MICROWAVE CHARACTERIZATION TOOLS FOR THIN FILM CIRCUITS

As the speed of modern electronics increases, thin film dielectric materials are becoming increasingly important circuit elements for integrated electronics, communications, and computing applications. It is important to characterize thin-film dielectric materials over a broad frequency range to ensure adequate performance at the ever-increasing frequencies used by these devices. Also, new thin film materials are being developed that incorporate some functionality in the materials themselves, such as voltage-tunable ferroelectrics.

NIST researchers have developed an experimental method for determining the broadband permittivity of thin-film samples at frequencies up to 40 GHz using coplanar waveguide (CPW) measurements and finite element simulations. This method uses the multiline TRL calibration techniques previously developed at NIST, and is convenient for evaluating thin-film samples with minimal preparation, since metallic conductors can be deposited directly on the film surface in most cases. This technique complements existing thin-film permittivity measurements developed at NIST based on microstrip devices. Consistent values for the permittivity of barium strontium titanate thin films have been successfully extracted for three different cpw geometries incorporated on the same thin-film sample. Measurements of lumped-element devices also on the same sample give consistent permittivity values as well, allowing the frequency range of this technique to be extended to lower frequencies. The simplicity of this technique will allow new materials to be evaluated rapidly for microwave frequency applications.
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PHASE SENSITIVE NEUTRON REFLECTOMETRY DESCRIBES THE STRUCTURE OF A MEMBRANE-MIMETIC BIOMATERIAL

Scientists at the NIST Center for Neutron Research (NCNR) and the Department of Surgery at Emory University in Atlanta, GA, are using phase-sensitive neutron reflectometry to characterize the structure of a medically relevant membrane-mimetic system composed of a polyelectrolyte cushion, a terpolymer, and a self-assembled phospholipid monolayer. Neutron reflectometry is a powerful probe of the compositional depth profile of multilayer structures on planar supports, with a resolution that can be less than a nanometer.

Cell membranes, which form the boundary between extracellular and intracellular compartments, regulate many crucial biological processes. Planar supported mimics of cell membranes are of great interest for the study of membrane structure/function relationships and for the development of biomaterials. The polymeric lipid bilayer membrane under study is being developed

as a coating for artificial vascular grafts. The water-swellable polyelectrolyte acts as a support for the biomembrane, not unlike the cytoskeletal support found in mammalian cell membranes. The terpolymer acts as a cushion for the phospholipid layer. The lipid is polymerizable so that it can be anchored to the terpolymer. This gives the membrane mimic stability under shear forces such as those imparted by blood flowing through the vascular system. The goal of this research is to determine the water distribution in the different layers of the biomaterial and to infer if the phospholipid layer exists as a single monolayer on top of the terpolymer. Phase-sensitive neutron reflectometry, developed at the NCNR, makes it possible to directly obtain a unique depth profile of the measured system without any prior knowledge of its composition. NIST's recent neutron reflectometry experiments have shown that the polyelectrolyte cushion layer contains 40 % water and the terpolymer layer contains 10 % water in a membrane containing just those two layers. However, upon addition of the phospholipid layer, the polyelectrolyte layer becomes less hydrated and the terpolymer layer undergoes significant structural rearrangement. The results also show a 30 Å thick layer at the membrane surface, consistent with the formation of a single phospholipid monolayer. This new information now can be used to construct a better polymeric lipid membrane mimic containing a biologically active membrane protein.

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PUBLICATION AVAILABLE ON KOREA'S STANDARDS AND CONFORMITY ASSESSMENT SYSTEM

A NIST guest researcher from the Korean Agency for Technology and Standards (KATS), prepared a comprehensive report on "Standardization and Conformity Assessment in the Republic of Korea" (NISTIR 6960). The publication describes the national system for standardization and conformity assessment in the Republic of Korea. It also compares U.S. entities with Korean entities. A copy of the publication may be accessed at: ts.nist.gov/ts/htdocs/210/ncsci/osc.htm

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MEASUREMENTS COMPLETED FOR 20 RM 8240 STANDARD BULLETS

Scratches on a bullet recovered at a crime scene can be as incriminating as fingerprints. Unfortunately, methods for analyzing these tell-tale forensic "signatures" still entail manual comparisons, making firearms-ballistics databases impractical. NIST scientists, with input from industrial and government partners, developed "standard" bullets—bullet-shaped artifacts with a series of surface profiles that can be used for testing the forensic equipment and operators. These standard bullets, officially called Reference Material (RM) 8240, are still under-going final testing.

Surface profile measurements of 20 RM 8240 standard bullets were completed in April 2003. These measurements were performed with a newly developed NIST bullet signature measurement system. A NIST proposed parameter and algorithm are used for quantifying the bullet signature differences between the RM bullets and a virtual standard for the bullet signatures. The virtual standard is a set of six digitized surface profile signatures, originally obtained from six master bullets shot at the Bureau of Alcohol, Tobacco and Firearms and the Federal Bureau of Investigation, using six different guns. By using the virtual signature standard as tool path information in a numerically controlled diamond turning machine at the NIST instrument shop, the 20 RM bullets were produced. The NIST proposed algorithm uses auto- and cross-correlation functions (ACF and CCF) for quantifying bullet signature differences. When the two compared signatures are exactly the same (point by point), their CCF would be equal to 100 %. Measurement results showed that the CCFs for all 120 profiles (6 profiles on each of 20 bullets) are higher than 95 %, and most of them are higher than 99 %. These results demonstrate the high reproducibility of both the manufacturing process and the measurement system for NIST RM bullets.

A NIST associate from Drexel University and NIST scientists developed the measurement program. The measurement data will undergo further statistical analysis at NIST. A NIST workshop is scheduled for early June, preceding availability of the RM bullets to forensic agencies nationwide.

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AFM PROBE DEVELOPED FOR M^3

A new type of probe has been developed for the molecular measuring machine (M^3) that allows the imaging of non-conductive samples. M^3, a one-of-a-kind instrument designed to measure to nanometer accuracy the positions of features located anywhere within a 50 mm × 50 mm area, was developed at NIST. It has been a long-standing plan for M^3 to eventually add an atomic force microscope (AFM) probe to increase the variety of samples that can be measured. Now, with the help of a NIST associate from the Ilmenau Technical University in Ilmenau, Germany, it has been accomplished.

Since M^3 operates in a vacuum environment, and because the space available for the probe is very limited, it was impractical to use a typical, commercial AFM probe that senses the force by measuring the deflection of a cantilever using an optical-beam, lever arm. Instead, researchers implemented an AFM probe based on measuring the shift in resonant frequency of a tuning-fork sensor when a mounted tip comes into the force-interaction zone of the sample surface. For this scheme, the needed probe hardware is minimal, there are no critical alignment issues, and the same pre-amplifier that is normally used for sensing the tunneling current when using the scanning tunneling microscope probe can be used to amplify the tuning-fork signal. The first images recently have been acquired using this tuning-fork AFM probe.

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NIST SECURITY SPECIALISTS PUBLISH ROLE-BASED ACCESS CONTROL BOOK

NIST scientists recently published a new book, entitled *Role-Based Access Control.* Designed for software developers, security administrators, and students, the book covers all aspects of role-based access control (RBAC), an advanced access control model introduced in 1992. It explains the RBAC model and how it can be used by organizations to provide better security at a reduced cost. An independent study by the Research Triangle Institute found that RBAC has saved U.S. industry more than $600 million and that NIST's research was responsible for nearly half of this savings. The Web site is csrc.nist.gov/rbac.

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NIST COLLABORATES ON STUDY OF ADAPTIVE CHARACTERIZATION OF JITTER NOISE IN SAMPLED HIGH-SPEED SIGNALS

Researchers at NIST have developed an adaptive functional data analysis method to characterize random timing errors in high-speed sampled signals measured by sampling oscilloscopes. On average, jitter noise blurs a measured signal and reduces its power in the spectral domain. However, given an estimate of the standard deviation of the jitter noise, one can correct the measured power spectrum. This correction dramatically reduces prediction error and is essential for characterizing the impulse response function of high-speed sources and detectors in optical fiber communications systems at high frequencies (up to 50 GHz).

To estimate the standard deviation of jitter noise, many (hundreds to thousands) jittered signals are measured. Researchers first align the signals based on estimates of time translation errors, determined from a cross-correlation analysis of all possible pairs of signals. Based on the time-varying sample variance of the aligned signals and estimated derivatives of the noise-free signal at each time sample, they estimate the standard deviation of the jitter noise. Since there is no analytic model for the noise-free signal, the derivative is estimated using a regression spline model for the signal. Due, in part, to the non-linear nature of the estimation procedure, the initial estimate of the standard deviation of the jitter noise is biased. A computationally intensive Monte Carlo resampling scheme called the parametric bootstrap is used to estimate this bias. Based on the bootstrap estimate of bias, the jitter standard deviation estimate is adaptively corrected.

The results of this study will appear in an upcoming edition of the *IEEE Transactions on Instrumentation and Measurement.*

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NIST STUDIES EXTENDING THE SCOPE OF ELECTRON-BEAM TOMOGRAPHY

Tomography is the science of reconstructing three-dimensional structures from a set of two-dimensional images—for example, a set of absorption photographs of the same object taken from different angles, using penetrating radiation such as radio waves, x rays, or electron beams. Reconstruction of the full three-dimen-

sional structure from such images requires a model of the attenuation of the radiation beam as it passes through the object.

Electron microscopy can be used to extend these concepts to the nanoscale. While most studies have emphasized obtaining excellent spatial resolution on small samples, samples larger than 1 μm have received little consideration. For such samples, electrons are sure to undergo multiple scattering, which violates the standard assumption of exponential attenuation used in tomography.

New theoretical analysis shows that even if multiple scattering is present, tomography may be performed by generalizing the relationship of the detected signal to the material thickness. Little else in the analysis or the instrument needs to change. A paper published in the June 2, 2003, issue of *Applied Physics Letters* describes a simulation of tomographic reconstruction using scanning transmission electron micrographs of a model photonic band gap crystal. A simulated tomographic reconstruction of a polymer sample over 8 micrometers on a side was achieved.

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SINGLE ATOMS DELIVERED ON DEMAND

Scientists at NIST have demonstrated a novel source of atom flux that can provide one, and only one, atom essentially whenever it is needed—the first time such control over neutral atom delivery has been achieved. Reporting in the May 5, 2003 issue of *Applied Physics Letters,* researchers show that the population of chromium atoms in a magneto-optical trap can be stabilized at the single-atom level with a probability of nearly 99 % by using fast feedback control over trap loading and dumping, together with very-high fluorescence detection efficiency. Further, research shows that the single atoms can be ejected from the trap at rates of up to 10 Hz, while still maintaining at least a 90 % chance of ejecting exactly one atom.

Such deterministic control of single atoms has a wide range of potential applications, including quantum information processing, atom-by-atom nanotechnology, and fundamental studies of atom-to-atom interactions.

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SCIENTISTS STUDY WHIRLPOOLS IN FERMION SUPERFLUIDS

The structure of vortices and vortex rings in Bose-Einstein condensates (BECs) has been a subject of intense interest during the past few years and has been studied experimentally at JILA and theoretically in Gaithersburg. Vortices in BECs are similar to the familiar whirlpool motion that forms around a bathtub drain when water flows out, yet they are capable of circulating indefinitely due to the superfluid properties of BECs.

Vortices exist also in superfluids consisting of fermion particles, such as electrons in a superconductor, liquid ^{3}He, or neutron stars. Despite extensive investigations over the past 30 years, the energy and density profile of a vortex in a fermion superfluid had not yet been calculated from first principles. There is even controversy over the applicable characteristic length scale: whether it is the so-called Bardeen-Cooper-Schrieffer (BCS) coherence length, or a much smaller length that is inversely proportional to the Fermi energy of the system.

Scientists from NIST, in collaboration with colleagues at Niels Bohr Institute (Denmark), and the University of Calgary (Canada), have now performed the first such calculation for a superfluid fermion gas. Their results, published in *Physical Review Letters* (Vol. 90, p. 210402, 2003), establish that the characteristic size of the vortex core is indeed proportional to the BCS coherence length. Furthermore, they make the first quantitative prediction of the critical rotational frequency at which a vortex will appear in the ground state of a rotating fermion superfluid. Discovery of such a state would be a definitive signature of superfluidity in a fermion gas, which has been long sought but not yet observed.

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DATA AVAILABLE ON ATOMIC SPECTRAL TABLES FOR THE CHANDRA X-RAY OBSERVATORY

Spectral tables for four cosmically abundant elements (Ne, Mg, Si, and S) in the wavelength region of interest for the Chandra X-Ray Observatory, which is roughly 2 nm to 17 nm, have been critically compiled with partial support from the Chandra Emission Line Project. These data also will be useful for the diagnostics of plasmas encountered in fusion-energy research.

This is the first extensive critical compilation for these spectra. Data for about 3300 spectral lines of 24 ions are tabulated. The compiled wavelengths and energy levels are from experimental sources, while the transition probabilities originate mainly from recent calculations carried out with advanced, multiconfiguration computer codes, with relativistic terms included. Uncertainty estimates for the transition probabilities are also provided.

The data will be published in the *Journal of Physical and Chemical Reference Data.* They are now available as a database at physics.nist.gov/chandra. The database has a user interface that includes options to retrieve subsets of the data in several different formats. CONTACT: Larissa Podobedova,(301) 975-5832; larissa.podobedova@nist.gov or Karen Olsen, (301) 975-3286; karen.olsen@nist.gov.

HANDBOOK OF BASIC ATOMIC SPECTROSCOPIC DATA AVAILABLE ONLINE

NIST has made a handbook of basic atomic spectroscopic information available at physics.nist.gov/Handbook. The handbook is designed to provide a selection of the most important and frequently used atomic spectroscopic data in an easily accessible format.

The compilation includes data for the neutral and singly ionized atoms of all elements hydrogen through einsteinium (1 through 99). The wavelengths, intensities, and spectrum assignments are given in a table for each element, and the data for the approximately 12 000 lines of all elements also are collected into a single table, sorted by wavelength (a "finding list"). For the strongest and most persistent lines of each spectrum, the complete energy-level classifications are provided as are the transition probabilities, if available.

Linked data files make finding, identifying, and determining additional information about included transitions very quick and easy. Although the data for some spectra are not as complete as those found in NIST's Atomic Spectra Database (physics.nist.gov/asd), this compilation includes more recent data for many elements, particularly the heavier ones.

The atomic number and weight are listed for each element, as well as the naturally occurring isotopes and their isotopic mass, abundance, nuclear spin, and magnetic moment. The ground state and the ionization potential for the first and second spectra are given. The handbook also is packaged as zipped HTML files suitable for downloading to electronic books. Directions for downloading are included on the Web site.

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NIST RELEASES NATURAL VENTILATION DESIGN AND ANALYSIS TOOL

NIST has developed a software tool to assist designers of natural ventilation systems in buildings. The tool, Loop Design and Analysis (LoopDA), is integrated with NIST's existing multizone airflow analysis program, CONTAMW.

Prior to this development, designers were unable to perform the engineering analyses required for natural ventilation system design. This limitation was inhibiting the development and application of new natural ventilation technologies in buildings, which have the potential for increasing energy efficiency and improving indoor environments and occupant productivity. LoopDA implements the Loop Equation Design Method for sizing openings of natural ventilation in buildings, and allows direct consideration of the dynamics of stack and wind-driven airflows.

LoopDA is available for download from NIST at www.bfrl.nist.gov/IAQanalysis.
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FIRST PRINCIPLES CALCULATIONS OF Pb AND O VACANCIES IN PEROVSKITE COMPOUNDS PERFORMED

Theorists at NIST have performed first principles calculations that have demonstrated that Pb-O vacancy pairs can be a significant source of "random" electric fields in Pb-based perovskite compounds, materials under development for electrostrictive transducers, actuators, and sonar devices for medical imaging and military applications.

Relaxor ferroelectrics exhibit useful physical properties, such as a high dielectric constant over a wide range of temperature and large electromechanical coupling constants. The known relaxors with the best properties are Pb-based compounds with the perovskite-type structure. Experiments indicate that inducing a 1 % to 5 % concentration of Pb and O vacancies significantly affects their physical properties. Because theories of relaxor behavior are based on interactions between polar nanoregions, and with local random electric fields, it is essential to characterize the polarization and electric fields generated by Pb and O vacancies.

First principles calculations were used to study the electrostatics of Pb and O vacancies in the Pb-based perovskite $PbTiO_3$. The calculations suggest that at low concentrations Pb and O vacancies are paired into nearest neighbor divacancy pairs. Calculating the dipole moment of this pair required a novel application of the modern theory of polarizability. The dipole moment of the divacancy is greater than the dipole moment per unit cell in defect-free Pb-based ferroelectrics, indicating that Pb-O vacancy pairs can be a significant source of local random fields in Pb-based perovskites. This result can have important implications for the performance of relaxor ferroelectric materials in electronic devices.

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NIST HOSTS WORKSHOP ON LANGUAGE RECOGNITION

NIST hosted the 2003 NIST Language Recognition Workshop at NIST in April 2003. Held in cooperation with Department of Defense (DoD) sponsors, the workshop reviewed the recent evaluation of language recognition research systems in this area. Six sites representing organizations from around the world participated in the evaluation demonstrating current state-of-the-art capabilities for detection of the languages used in segments of conversational telephone speech. The participants were MIT Lincoln Laboratory, the OGI School of Science and Engineering of the Oregon Health & Science University working in collaboration with the Institute of Acoustics of the Chinese Academy of Sciences, the Speech Research Lab of Queensland University of Technology, R523 (DoD), the Department of Electrical Engineering of the University of Washington, and a collaboration of the Institut de Recherche en Informatique de Toulouse and the Laboratoire Dynamique du Langage (Lyon).

In the evaluation, each system was presented with numerous test segments of conversational speech with durations of approximately 3 s, 10 s, or 30 s. The system had to decide for each of 12 target languages whether the speech segment was in that particular language. The target languages were Arabic, English, Farsi, French, German, Hindi, Japanese, Korean, Mandarin, Spanish, Tamil, and Vietnamese. The test segments came from previously collected corpora of telephone conversations in each of these languages as well as in Russian.

NIST researchers gave presentations summarizing the overall performance results and analyzing how performance varied with segment duration, speaker gender, and the languages being tested. One surprising finding was that language detection performance generally was more superior on female speech than on male speech.

NIST conducted the last such evaluation and workshop in 1996. Two of the participating sites in 2003, MIT and OGI, also participated in the 1996 evaluation. Each of these sites had results this year that were considerably superior to their performance seven years earlier.

More information about the 2003 NIST Language Recognition Evaluation is available at www.nist.gov/speech/tests/lang/index.htm.

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NCNR'S USER-FRIENDLY RIETVELD SOFTWARE HAS WIDE IMPACT ON STRUCTURE ANALYSIS

Rietveld refinement allows crystallographic analyses to be performed by profile fitting of powder diffraction data. It is widely applied in chemistry, geology, materials science, condensed-matter physics, engineering, and most recently in the life sciences. Use at the NIST neutron source began almost immediately after Hugo Rietveld's seminal paper was published in 1969. The Rietveld technique is of particular value for neutron work, as it offers access to the many advantages of neutron diffraction with short data collection times and without the requirement for large single crystals.

Since the 1970s, three generations of neutron diffraction instrumentation have been built at the NIST Center for Neutron Research (NCNR); the current instrument is the most versatile and highest resolution neutron powder diffractometer in the United States. During this same period, however, development efforts in Rietveld software lagged behind. This changed significantly when the NCNR developed EXPGUI, a software package to aid users of Los Alamos' General Structure Analysis System (GSAS) package. GSAS is considered to be the most sophisticated and powerful Rietveld package, but it has a very dated command-line user interface that hinders potential users. With EXPGUI, users access GSAS via a modern, user-friendly graphical user interface.

The EXPGUI software continues to draw thousands of people to the NIST Web site and to sites in Australia, Canada, and England where the EXPGUI Web pages are mirrored. In the past year alone, the EXPGUI documentation and tutorial Web pages were visited more than 100 000 times and the software was downloaded several thousand times.

For further information, see www.ncnr.nist.gov/xtal. CONTACT: Brian Toby, (301) 975-4297; brian.toby@nist.gov.

PHASE EQUILIBRIA DATA FOR ELECTRONIC CERAMICS PUBLISHED

The first volume of a collection of phase diagrams focused on the increasingly important field of electronic ceramics was presented to the American Ceramic Society (ACerS) at its annual meeting in April 2003. The new volume details the phase equilibria of dielectric Ti, Nb, and Ta oxide systems. More than 1100 diagrams are presented along with commentaries for each system written by knowledgeable associate editors.

The new volume is part of the acclaimed series, *Phase Equilibria Diagrams* (known formerly as *Phase Diagrams for Ceramists*) produced jointly by NIST and ACerS. The NIST/ACerS collaboration began in 1933 and has continued without interruption. This effort has produced 13 regular volumes, three general supplemental volumes, and four special topical volumes (two on high temperature superconductors, one on zirconium and zirconia systems, and the new volume on electronic ceramics). Overall, the series encompasses systems containing oxides; salts; semiconductor elements; borides, carbides, and nitrides for structural ceramics; high temperature superconductors; and electronic ceramics.

In addition to the new volume, a new cumulative index was presented to the society to serve as a guide to the 13 volumes, the annuals, and the special topical volumes. Further information may be found on the Web site of the American Ceramic Society at www.acers.org.
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NIST WRITES FIRST MEMS STANDARDS

The first microelectromechanical systems (MEMS) standards in the world will be published in the *Annual Book of ASTM Standards* this summer. The three-standard test methods are for measuring in-plane lengths, residual strain, and strain gradient. Written by a NIST staff member, these test methods are based on the research and analyses detailed in NIST Interagency Report 6779. The residual strain and strain gradient standard calculations can be performed on the NIST Web site (www.eeel.nist.gov/812/test-structures/) to facilitate quick and easy calculations.

MEMS is a rapidly growing component of the semiconductor industry. Applications for MEMS demand high performance and reliability. The standard test methods are crucial for tightening the variations in the parametric measurements between laboratories. These international standards are expected to facilitate international commerce in MEMS technologies and improve manufacturing yields.

All three test methods apply to thin films such as found in MEMS materials, which can be imaged using a non-contact optical interferometer. The first test method shows how to measure an in-plane length (or deflection) measurement, given that each end is defined by a distinctive out-of-plane vertical displacement. The second test method shows how to calculate the residual strain from two cosine functions that are used to model the out-of-plane shape of fixed-fixed beams. The third test method shows how to measure the strain gradient from a circular function that is used to model the out-of-plane shape of cantilevers.

The three test methods are under the jurisdiction of ASTM Committee E08 on Fatigue and Fracture and are the direct responsibility of Subcommittee E08.05 on Cyclic Deformation and Fatigue Crack Formation. CONTACT: Janet Marshall, (301) 975-2049; janet.marshall@nist.gov.

RESEARCHERS USE NEW METHOD FOR *IN SITU* TIP REGENERATION IN VACUUM

Using the NIST-developed molecular measuring machine (M^3), NIST researchers have implemented a method for in situ tip regeneration without having to break vacuum to change the tip. By scanning a blunt tip at 0.1 μm/s over the tops of gold-coated 50 nm diameter pillars with periodicity 200 nm (in two dimensions) and "pulsing" the tip (applying a voltage spike of a few volts over a few milliseconds) in low vacuum (10^{-3} Torr to 10^{-6} Torr), they easily generate a sharp tip. By looking at subsequent images of the pillars, researchers were able to determine how sharp the tip was. Usually, the tip is sharper than 100 nm for purposes of imaging the pillars, which are roughly 75 nm tall; sometimes it is sharper than 50 nm. If the tip is not deemed sharp enough, researchers wait until it is scanning along the tops of the pillars and pulse it again. Researchers used this technique to generate a tip that

then was used to write 10 nm wide lines on silicon via scanning probe oxidation, indicating the tip of the tip was not significantly more blunt than 10 nm. NIST researchers have also used regenerated tips to image 1 μm and ½ μm pitch patterns of a magnification standard.

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SENSITIVE MICROSENSORS RECOGNIZE CHEMICAL WARFARE AGENTS

Researchers at NIST have developed microsensors that detect nmol/mol quantities of chemical warfare agents (CWAs), including sarin (GB), tabun (GA) and sulfur mustard (HD). The recent results represent a significant step forward in the development of low power, CWA detectors for personal protection applications in both military and civilian settings. The project has been supported by the Defense Threat Reduction Agency.

The sensors are silicon-based microelectromechanical (MEMS) devices consisting of suspended 100 μm × 100μm heatable platforms that have metal oxide sensing films deposited on their surfaces. Gases that adsorb on the surfaces can change the electrical conductivities of the thin, nanostructured films which are typically tin oxide (SnO_2), titanium oxide (TiO_2), zinc oxide (ZnO), or iron oxide (Fe_2O_3). The unique features of these sensors are that they can easily be fabricated in arrays and operated in a dynamic temperature mode to generate varied electrical response "fingerprints" for specific gases. In contrast to other conductometric gas sensors, these microsensors can distinguish different analytes and respond much faster (typically in seconds).

Microsensor testing on the CWAs was performed at the Edgewood Chemical Biological Center (ECBC), a Department of Defense facility at Aberdeen Proving Ground, MD. In the tests, four-element arrays were exposed in air backgrounds to individual concentrations of GA, GB, and HD ranging between 4 nmol/mol and 200 nmol/mol. Good signal-to-noise was observed for all of the sensing films employed in these studies (SnO_2 and TiO_2), even at the lowest concentrations presented to the devices. Matched pairs of each of the two oxides were used, and excellent sensing reproducibility of the twins was observed. Good stability of the devices also was recorded for hours of CWA exposure. In addition, artificial neural network (ANN) signal processing methods were used to extract the most important and reliable analytical information from the complex temperature programmed responses. Initial ANN successes have demonstrated an ability to recognize individual agents and related molecular simulants and predict their concentrations. Future studies will determine the ultimate sensitivities of the devices as alarm triggers and investigate methods that ensure reliable performance even in the presence of interfering gases, such as diesel exhaust fumes.

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NIST DEVELOPS HIGH-RESOLUTION TECHNIQUE FOR CHARACTERIZATION OF NANOSCALE PATTERNS WITH SMALL ANGLE X-RAY SCATTERING

NIST has demonstrated the application of Small Angle X-ray Scattering (SAXS) as a new measurement method for the non-destructive characterization of nanoscale pattern size and shape at length scales needed for future technology nodes in the semiconductor industry. Current measurement methods such as scanning electron microscopy, atomic force microscopy, and optical scatterometry, face significant challenges in the characterization of dense, high aspect ratio, nanoscale features because, in general, smaller structures are increasingly difficult to measure. In contrast, precise measurements of nanoscale structures with the SAXS technique become easier with decreasing structural size.

SAXS measurements were performed at the Advanced Photon Source at Argonne National Laboratory on test arrays of lithographically prepared structures with dimensions spanning 90 nm to 300 nm with a precision on the order of 0.1 nm. Diffraction patterns provide average pitch and average line width over a large array of structures (ca. 40 μm × 40 μm beam spot size). The method has been successfully demonstrated on test structures, including line gratings and two-dimensional arrays of via-pads composed of organic photoresists, oxide, and low-k dielectrics. Because measurements are performed in transmission mode on standard wafers in ambient air without additional sample preparation and data collection times are on the order of a second, this technique provides the potential for high throughput processing characterization. The development of a laboratory-scale device based on commercially available sources is considered feasible and is currently being explored.

This work is supported in part by the Advanced Lithography Program of the Defense Advanced Research Projects Agency and the NIST Office of Microelectronics Programs. Technical assistance and

test samples were provided by IBM, Shipley, ExxonMobil, and International SEMATECH.

For further information, visit the Polymers Division Web site at www.nist.gov/polymers and search Polymers Web space for "photolithography."

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OVERVIEW OF THE U.S. APPROACH TO STANDARDS, CONFORMITY ASSESSMENT, AND METROLOGY AVAILABLE

NIST provides assistance to U.S. government agencies and industry in order to overcome or eliminate technical barriers to trade. Since these barriers are often due to differences in standards and conformity assessment practices between the United States and its trading partners, a NIST researcher has developed a CD ROM entitled, "An Overview of the U.S. Approach to Standards, Conformity Assessment, and Metrology." As part of a larger effort that includes workshops and published documents, the purpose of this CD ROM is to educate NIST staff and representatives of other U.S. and foreign government and private sector agencies about responsibilities for developing or using standards and conformity assessment. The compendium-like CD includes informative chapters on NIST, standards, conformity assessment, regulations, metrology, and global issues. It also contains numerous links to the Web sites of other organizations and resources in the global commu-nity. This free CD ROM will be available while quantities last.

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Standard Reference Materials

NIST DEVELOPS A STANDARD REFERENCE MATERIAL FOR PEANUT BUTTER

The Nutrition Labeling and Education Act of 1990 requires that information for selected nutrients be provided on labels for processed foods. In response, NIST has been working to provide food-matrix Standard Reference Materials (SRMs) with values assigned for the required nutrients. SRM 2387, Peanut Butter, is one in this series. SRM 2387 is intended for use as a primary control material for assigning values to in-house control materials and to validate analytical methods for measuring nutrients such as fat, protein, vitamins, and minerals. SRM 2387 is the first food-matrix reference material available from NIST with values assigned for amino acids, making the material potentially useful as a quality assurance tool for these and other nutrients in USDA's nutrient databases.

To study the robustness of analytical methods, AOAC International developed a nine-sector triangle in which foods are positioned based on their fat, protein, and carbohydrate content. The idea was that one or two foods within each sector should be representative of other foods within that sector when validating an analytical method. Similarly, one or two food-matrix reference materials in each sector can be used as control materials for other foods within that sector. NIST currently has food-matrix reference materials available within or along boundaries of all sectors except for the one in which peanut butter lies. Other foods in this sector include pasteurized processed cheese spread and beef bologna.

SRM 2387 also addresses the need for a reference material with values assigned for aflatoxins. Aflatoxins are highly carcinogenic metabolites of molds that may contaminate peanuts and other crops. This is the first reference material available from NIST that assigns values for aflatoxins.

NIST analysts provided data for certification of total fat and individual fatty acids, vitamin E, and several elements of nutritional interest (e.g., calcium, sodium, iron, zinc, etc.) in SRM 2387. NIST data were combined with data provided by other collaborators to assign certified values. Reference values for additional vitamins, protein, calories, aflatoxins, amino acids, etc. were generated from data provided solely by collaborating laboratories.

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NIST PLAYS ROLE IN KEEPING TIN CANS LEAD-FREE

When steel mills manufacture tin-plated sheet steel for food cans, they must test the tin (Sn) and the electroplating bath for lead (Pb) content. If lead is allowed to accumulate in the tin or the bath, it will become part of the tin coating and may leach into food stored in cans. In recent years, can makers reduced the allowable Pb content of tin plate in recognition of potential health risks in products used for foods. Steel mills typically purchase Sn anodes according to ASTM B 339 Standard Specification for Pig Tin, with a restriction of 50 μg/g Pb maximum. Residual amounts of anode tin

are typically remelted on site to form new anodes. Incoming and remelted tin anodes are analyzed by atomic emission spectrometry to meet material acceptance and process control requirements.

Tin-plate is a high-volume commodity made by many U.S. and foreign steel companies. About 3 million tons of tin-plate are manufactured and shipped from U.S. steel producers annually at a typical selling value of $800 per ton during 1999. Can makers purchase much of the tin-plate to manufacture products such as food and beverage cans, automotive filter cases, and paint cans.

Developed in cooperation with ASTM International, Standard Reference Material (SRM) 1727 Anode Tin is intended primarily for use in evaluating chemical and instrumental methods of analysis of refined pig tin for Pb content. SRM 1727 is certified for Pb content on the basis of analyses by isotope-dilution inductively-coupled plasma mass spectrometry. Information values are provided for 10 additional elements. SRM 1727 is sold in solid form (a block 30 mm on each side) for spectrometric analysis and may be chipped for use with chemical methods of analysis.

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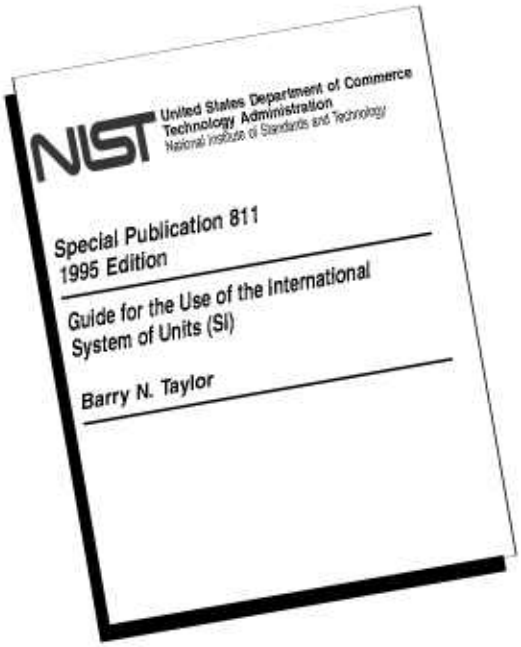
The International System of Units (SI)

A Guide for the Use of the Modern Metric System

NIST Special Publication 811, 1995 Edition



Uncertain about the International System of Units (universally abbreviated SI), the modern metric system used throughout the world? Do you need to know the proper way to express the results of measurements and the values of quantities in units of the SI? Do you need to know the NIST policy on the use of the SI? Then you need the 1995 Edition of the National Institute of Standards and Technology Special Publication 811, *Guide for the Use of the International System of Units (SI)*.

The 1995 Edition of the National Institute of Standards and Technology Special Publication 811, *Guide for the Use of the International System of Units (SI)*, by Barry N. Taylor, is now available.

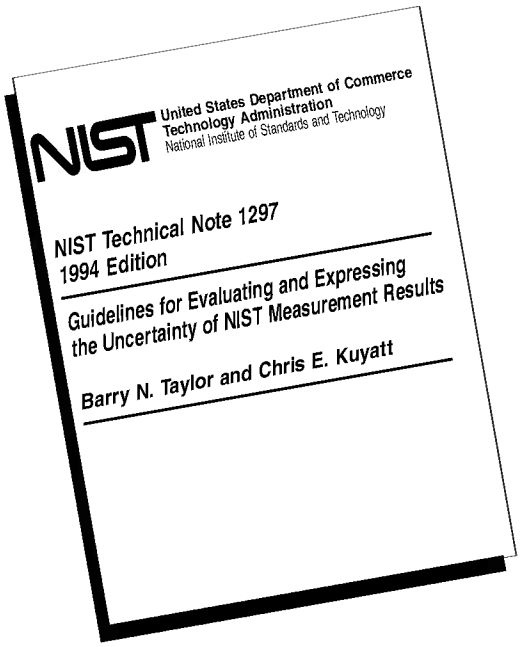
The 1995 Edition of SP 811 corrects a number of misprints in the 1991 Edition, incorporates a significant amount of additional material intended to answer frequently asked questions concerning the SI and SI usage, and updates the bibliography. The added material includes a check list for reviewing the consistency of written documents with the SI. Some changes in format have also been made in an attempt to improve the ease of use of SP 811.

The topics covered by SP 811 include:

- NIST policy on the use of the SI in NIST publications.
- Classes of SI units, those SI derived units that have special names and symbols, and the SI prefixes that are used to form decimal multiples and submultiples of SI units.
- Those units outside the SI that may be used with the SI and those that may not.
- Rules and style conventions for printing and using quantity symbols, unit symbols, and prefix symbols, and for spelling unit names.
- Rules and style conventions for expressing the results of measurements and the values of quantities.
- Definitions of the SI base units.
- Conversion factors for converting values of quantities expressed in units that are mainly unacceptable for use with the SI to values expressed mainly in units of the SI.
- Rounding numbers and rounding converted numerical values of quantities.

Single copies of the 84-page NIST SP 811, 1995 Edition, may be obtained by contacting the NIST Metric Program, 100 Bureau Drive, Stop 2000, Gaithersburg, MD 20899-2000; telephone: 301-975-3690; fax: 301-948-1416; email: metric_prg@nist.gov. NIST SP 811 is also available online at the NIST Web site entitled "NIST Reference on Constants, Units, and Uncertainty," physics.nist.gov/cuu.

Evaluating and Expressing the Uncertainty of Measurement Results



Uncertain about expressing measurement uncertainty? Do you need to know how NIST states the uncertainty of its measurement results and how you can implement their internationally accepted method in your own laboratory? Then you need the newly available 1994 edition of the National Institute of Standards and Technology Technical Note 1297, *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results.*

The 1994 edition of the National Institute of Standards and Technology Technical Note 1297, *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*, by Barry N. Taylor and Chris E. Kuyatt is now available.

The 1994 edition of TN 1297 includes a new appendix—Appendix D—which clarifies and gives additional guidance on a number of topics related to measurement uncertainty, including the use of certain terms such as accuracy and precision. Very minor word changes have also been made in a few portions of the text of the 1993 edition in order to recognize the official publication in October 1993 by the International Organization for Standardization (ISO) of the *Guide to the Expression of Uncertainty in Measurement* on which TN 1297 is based. However, the NIST policy on measurement uncertainty, Statements of Uncertainty Associated with Measurement Results, which is reproduced as Appendix C of TN 1297, is unchanged.

It is expected that the 1994 edition of TN 1297 will be even more useful than its immediate predecessor, the 1993 edition, of which 10 000 copies were distributed worldwide.

Those United States readers who wish to delve into the subject of measurement uncertainty in greater depth may purchase a copy of the 100-page ISO *Guide* from the Sales Department of the American National Standards Institute (ANSI), 105-111 South State Street, Hackensack, NJ 07601. Copies may also be purchased from the ISO Central Secretariat, 1 rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland.

Single copies of the 20-page TN 1297 may be obtained from the NIST Calibration Program, 100 Bureau Dr., Building 820, Room 236, Stop 2330, Gaithersburg, MD 20899-2330, telephone: 301-975-2002, fax: 301-869-3548.

NIST Technical Publications

Periodical

Journal of Research of the National Institute of Standards and Technology—Reports NIST research and development in metrology and related fields of physical science, engineering, applied mathematics, statistics, biotechnology, and information technology. Papers cover a broad range of subjects, with major emphasis on measurement methodology and the basic technology underlying standardization. Also included from time to time are survey articles on topics closely related to the Institute's technical and scientific programs. Issued six times a year.

Nonperiodicals

Monographs—Major contributions to the technical literature on various subjects related to the Institute's scientific and technical activities.

Handbooks—Recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies.

Special Publications—Include proceedings of conferences sponsored by NIST, NIST annual reports, and other special publications appropriate to this grouping such as wall charts, pocket cards, and bibliographies.

National Standard Reference Data Series—Provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated. Developed under a worldwide program coordinated by NIST under the authority of the National Standard Data Act (Public Law 90-396). NOTE:The Journal of Physical and Chemical Reference Data (JPCRD) is published bimonthly for NIST by the American Institute of Physics (AIP). Subscription orders and renewals are available from AIP, P.O. Box 503284, St. Louis, MO63150-3284.

Building Science Series—Disseminates technical information developed at the Institute on building materials, components, systems, and whole structures. The series presents research results, test methods, and performance criteria related to the structural and environmental functions and the durability and safety characteristics of building elements and systems.

Technical Notes—Studies or reports which are complete in themselves but restrictive in their treatment of a subject. Analogous to monographs but not so comprehensive in scope or definitive in treatment of the subject area. Often serve as a vehicle for final reports of work performed at NIST under the sponsorship of other government agencies.

Voluntary Product Standards—Developed under procedures published by the Department of Commerce in Part 10, Title 15, of the Code of Federal Regulations. The standards establish nationally recognized requirements for products, and provide all concerned interests with a basis for common understanding of the characteristics of the products. NIST administers this program in support of the efforts of private-sector standardizing organizations.

*Order the **following** NIST publications—FIPS and NISTIRs—from the National Technical Information Service, Springfield, VA 22161.*

Federal Information Processing Standards Publications (FIPS PUB)—Publications in this series collectively constitute the Federal Information Processing Standards Register. The Register serves as the official source of information in the Federal Government regarding standards issued by NIST pursuant to the Federal Property and Administrative Services Act of 1949 as amended, Public Law 89-306 (79 Stat. 1127), and as implemented by Executive Order 11717 (38 FR 12315, dated May 11, 1973) and Part 6 of Title 15 CFR (Code of Federal Regulations).

NIST Interagency or Internal Reports (NISTIR)—The series includes interim or final reports on work performed by NIST for outside sponsors (both government and nongovernment). In general, initial distribution is handled by the sponsor; public distribution is handled by sales through the National Technical Information Service, Springfield, VA 22161, in hard copy, electronic media, or microfiche form. NISTIR's may also report results of NIST projects of transitory or limited interest, including those that will be published subsequently in more comprehensive form.

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